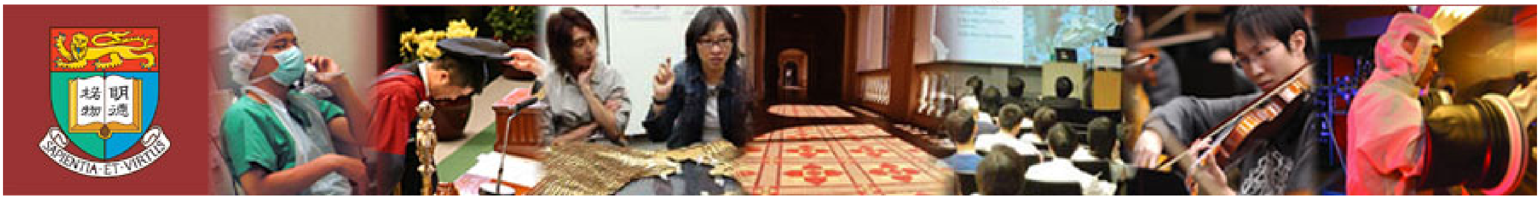


Identification and discrimination of /t^h/ and /k^h/ by children with cleft palate and posterior placement

Cho Ka Wun, Queenie

A dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science (Speech and Hearing Sciences), The University of Hong Kong, June 30, 2007.

Identification and discrimination of /t^h/ and /k^h/ by children with cleft palate and posterior placement

Cho Ka Wun, Queenie

Abstract

The aim of this study was to determine the abilities of children with repaired cleft palate who demonstrated posterior placement of alveolar targets (Group P) in the perception of /t^h/ and /k^h/, compared with two age-matched control groups: children with repaired cleft palate but without posterior placement (Group NP) and normally developing children (Group N). Eight age-matched children in each of these three groups participated in identification and discrimination tasks using eight synthetic stimuli along a speech continuum varying from /t^h/ to /k^h/. Group P children with repaired cleft palate and posterior placement identified the speech stimuli at chance level along the /t^h/ to /k^h/ continuum while both control groups (Group NP and Group N) perceived the stimuli into two discrete categories with a distinct phonemic boundary between /t^h/ and /k^h/. No significant group differences were found between the three groups of children in the discrimination task. These results, which suggest that children with repaired cleft palate and posterior placement have an identification deficit related to their production errors without a concomitant discrimination problem, contribute to the discussion of the underlying speech processing problems in these children.

Cleft lip and palate occur very early in the embryo and are present at birth (Peterson-Falzone, Hardin-Jones, & Karnell, 2001). The structural defects affect 1 in every 750 new born babies (McWilliams, Morris, & Shelton, 1990). The prevalence of cleft palate in Chinese population is 1.2 per 1000 live births (Cooper et al., 2000). Children born with cleft lip and palate are at risk for resonance, articulation, and expressive language problems that may impair communication for many years (Peterson-Falzone et al., 2001). Children with cleft palate have more difficulty in producing pressure consonants including plosives, fricatives and affricates, which require higher intraoral air pressure than other classes of consonants (Peterson-Falzone et al., 2001). Some speakers with cleft palate use substitutions termed compensatory articulations for some of the high-pressure sounds (McWilliams et al., 1990). Examples of compensatory articulations are glottal stops, pharyngeal stops, pharyngeal and/or laryngeal fricatives, and nasal fricatives (Santelmann, Sussman, & Chapman, 1999).

Children with cleft palate are at risk for both phonetically and phonologically based speech disorders. Phonetic errors in this population occur as a result of structural deviation associated with the cleft. Phonological errors may occur in relation to either general expressive language delay or physical constraints imposed by the cleft. The articulatory errors may initially occur as a result of structural limitations imposed by the cleft lip and palate and become integrated into the child's developing phonological system over time (Chapman, 1993). A consistent finding throughout the literature is the tendency of many children with cleft palate to use posterior placement or the process of backing, which has been described by some authors as a secondary phonological disorder that originates as a primary phonetic deviance (Peterson-Falzone et al., 2001; Russell & Grunwell, 1993).

Although there have been many descriptions of speech production errors in children with cleft palate (e.g. Gibbon, Ellis, & Crampin, 2004; Hardin-Jones & Jones, 2005), there have been few investigations on cleft palate children's ability to discriminate or identify phonological contrasts. The speech sound discrimination skills of seven and eight-year-old cleft palate children were investigated previously by Finnegan (1974) showing that children with cleft palate performed poorer in the discrimination tasks than normal age-matched controls. Several studies of children with phonological disorders have demonstrated that perceptual deficits were specific to the production errors (e.g. Groenen, Maassen, Crul, & Thoonen, 1996). The relation between speech perception and articulatory deficits in diverse groups of subjects were demonstrated in various studies (Hoffman, Daniloff, Bengoa, & Schuckers, 1985; Monnin & Huntington, 1974; Ohde & Sharf, 1988; Raaymakers & Crul, 1988; Rvachew & Jamieson, 1989). Hoffman, Daniloff, Bengoa, and Schuckers (1985) and Ohde and Sharf (1988) found that children with articulation problems had problems distinguishing /r/ from /w/ consistently. Monnin and Huntington (1974) found a specific relation between identification and production of /r/-/w/ contrasts in children with speech problems. Raaymakers and Crul (1988) investigated the final /s-ts/ contrast and found a specific relation between perception and production. Rvachew and Jamieson (1989) studied the perception of fricatives in children with a functional articulation disorder and found that their production errors may reflect speech perception errors.

Whitehill, Francis & Ching (2003) investigated the ability of children with repaired cleft palate and posterior placement of alveolar targets (e.g. /t^h/ → /k^h/) to identify /t^h/ versus /k^h/ targets from a range of synthetic stimuli. Participants from two control groups, children with repaired cleft palate but without posterior placement (Group NP) and normally developing children without cleft palate (Group N), performed similarly on the identification task. The children in both control groups were able to identify the stimuli appropriately, and showed a clear phonemic boundary between /t^h/ and /k^h/. In contrast, the children with cleft palate in the posterior placement group (Group P) demonstrated almost chance-level performance and showed no clearly defined division of the phonemic boundary across the range of synthetic /t^h/ and /k^h/ stimuli. A possible explanation is that children with cleft palate and posterior placement had a perceptual bias related to their own production error, demonstrating a production-specific perception disorder (Raaymakers & Crul, 1988; Whitehill et al., 2003).

Speech perception involve a series of processes, including a preliminary auditory analysis, further auditory and phonetic feature analysis, and the ecoding of phonetic features into a phonemic representation (Cutting & Pisoni, 1978; Pisoni & Sawusch, 1975). At any stage in this process, information can be placed in short-term memory. Auditory processing includes a preliminary analysis and is related to auditory short-term memory, whereas phonetic processing includes phonemic labeling strategies and is related to phonetic memory (Baddeley, 1992). Both identification and discrimination tasks have been used in order to distinguish the different processes in the auditory perception of speech (Groenen et al., 1996).

An identification task requires a phonemic judgment, and thus decisions are based primarily on the phonetic properties and features represented in phonetic short-term memory. The decisions involved in a discrimination task may be based on information from both phonetic and auditory memory (Liberman, Harris, Hoffman, & Griffith, 1957). Early studies in speech perception focused on the relationship between discrimination and classification of speech sounds on a stimulus continuum (Liberman et al., 1957). The hypothesis was that discrimination of certain speech sounds would be limited by classification. Two different speech stimuli would be discriminated only to the extent that they were classified differently. This is known as categorical perception (Eimas, 1963).

An identification task, rather than a discrimination task, was selected by Whitehill et al. (2003), since the identification task, which involved phonemic judgment, were considered more relevant to investigations of phonological disorder than a discrimination task (Groenen, Maassen, & Crul, 1998; Raaymakers & Crul, 1988; Rvachew & Jamieson, 1989). However, given the poor performance of the participants with cleft palate and posterior placement (Group P) in the identification task, further research was indicated, more specifically, a discrimination task was recommended in order to identify the locus of breakdown in the perceptual abilities of the children with repaired cleft palate (Whitehill et al., 2003).

The aim of the present study was to determine if children with repaired cleft palate and posterior placement demonstrate difficulty in the perception of place of articulation. The present study was an extension of the study of Whitehill et al. (2003), but children were tested on both identification and discrimination tasks for the /t^h/ - /k^h/ contrast. The performance of the group of children with cleft palate and posterior placement was compared with two control groups: children with repaired cleft palate but without posterior placement and normally developing children without cleft palate. The subjects' performance in identification and discrimination was compared so as to locate the breakdown level of the perceptual processing deficits, if any, in the group of children with cleft palate and posterior placement.

Method

Participants

Three groups of children participated in this experiment. The groups were matched in age and all the children were native Cantonese speakers. Group P consisted of eight children (mean age = 8;11, range = 6;0 – 12;06) with repaired cleft palate and with posterior placement in production of alveolar sounds (e.g. /t/ → [k]). Group NP consisted of eight children (mean age = 9;04, range = 6;09 – 12;06) with repaired cleft palate. These children did not show posterior placement of alveolar sounds but all demonstrated other speech production errors (e.g. /ts/ → [t]). These two groups were recruited from the Prince Philip Dental Hospital Cleft Lip and Palate Centre. Most of the children had received speech therapy previously except two children in Group P (P3 and P4). Three children (P5, P7 and NP6) were reported to have recurrent otitis media (ROM) but no ear infection was reported by the parents at the time of testing. The third group (Group N) consisted of eight normally developing children (mean age = 9;02, range = 6;04 – 12;03) without any speech production errors. They were recruited from the local community. The details of participants including age, sex and type of cleft are shown in Table 1.

Table 1. Participant details.

Participant	Age	Sex	Type of cleft
P1	6;0	M	SC
P2	6;02	M	L UCLP
P3	7;04	F	R UCLP
P4	8;01	M	L UCLP
P5	10;02	M	BCLP
P6	10;07	M	L UCLP
P7	10;09	M	L UCLP
P8	12;06	M	L UCLP
NP1	6;09	M	BCLP
NP2	6;10	M	BCLP
NP3	7;11	M	R UCLP
NP4	8;11	M	BCLP
NP5	10;06	F	R UCLP
NP6	10;05	M	BCLP
NP7	10;11	M	R UCLP
NP8	12;06	M	L UCLP
N1	6;04	M	-
N2	6;05	M	-
N3	7;08	M	-
N4	8;10	M	-
N5	10;06	F	-
N6	10;10	M	-
N7	10;11	M	-
N8	12;03	F	-

Notes. P = children with repaired cleft palate and posterior placement of alveolar consonants; NP = children with repaired cleft palate and no posterior placement; N = normally developing children; BCLP = bilateral cleft lip and palate; R UCLP = unilateral right cleft lip and palate; L UCLP = unilateral left cleft lip and palate; CP = cleft palate only; SC = Submucous cleft; Dashes indicate not applicable.

Screening Procedures

All participants were reported by their parents to have no learning disabilities, and no history of hearing problems or speech and language problems, indicating normal levels of cognitive, motor and perceptual functioning. All children passed a bilateral pure-tone audiometric screening at 20dB HL on 250, 500, 1000, 2000, 4000 Hz (International Organization for Standardization, 1985).

Part I of the Cantonese Segmental Phonology Test (CSPT; So, 1993) and a deep test were conducted to determine the participants' speech errors. Part I of CSPT contains 31 picture items in which each Cantonese phoneme was sampled at least once. A deep test (Appendix A) consisting of 36 picture items was administered to determine if the participants demonstrated posterior placement of the Cantonese alveolar targets. Each Cantonese alveolar syllable – initial phoneme (/t, t^h, s, ts, ts^h, l/) was sampled at least five times in varying vowel and final consonant contexts at monosyllabic and disyllabic word levels. All participants were able to name the pictures spontaneously in the speech tests. The productions were recorded in a quiet room using a Sony Portable Minidisc Recorder MZ-R90 and a Dicsong EM-720 clip-on microphone anchored to the participants' clothing.

The participants' productions were transcribed live by the investigator using broad International Phonetic Alphabet (IPA) transcription. All productions were re-transcribed by the investigator and another final year speech and hearing sciences student from audio recordings. Interjudge reliability score was 91% (942/1036) which was calculated by dividing the number of agreements by the total number of agreements and disagreements for phonetic transcriptions of the participants' speech productions. The normally developing children in Group N produced no speech errors in the CSPT or the deep test. The production errors of the alveolar targets by children in Group P and Group NP were reported in Table 2.

Table 2. Production errors of children in Group P and Group NP for alveolar targets on the Cantonese Segmental Phonology Test and the Deep Test.

	Realizations of Targets (Incidence)					
Participant	**/t/**	**/t^h/**	**/s/**	**/ts/**	**/ts^h/**	**/l/**
P1	[ʔ] 3/8	[$t^{ʕ}$] 3/10	[ʕ] 9/9	[ʔʕ] 9/9	[h] 4/9	
P2	[h] 2/8	[h] 5/10	[ʕ] 3/9	[ʔʕ] 2/9	[ʔʕ] 2/9	
			[h] 6/9		[h] 4/9	
P3	[k] 1/8	[k^h] 4/10				
P4	[k] 3/8	[k^h] 3/10				
P5	[k] 2/8	[k^h] 2/10				
P6		[k^h] 2/10				
P7	[k] 2/8			[tɬ] 4/9		
P8	[k] 3/8	[k^h] 1/10	[s^N] 10/10	[$tɬ^N$] 9/9		
NP1			[ɬ] 4/10			
			[t] 1/10			
			[s^j] 1/10			
NP2			[s^j] 3/10			
NP3			[ɬ] 9/10	[tɬ] 7/9	[tɬ] 2/9	
NP4	[Ø] 1/2		[s^{NS}] 3/4	[ts^{NS}] 2/3		
NP5			[ɬ] 2/10	[t] 5/9	[s]1/9	
			[$s^{ɬN}$] 5/10			
NP6			[$s^{ɬN}$] 6/10		[ts^N] 6/9	
NP7						
NP8			[h] 1/10			
			[ɬ] 3/10			

The children in Group P demonstrated posterior placement for alveolar targets with at least two incidences. Two children (P1 and P2) demonstrated posterior placement for alveolar targets by substituting the alveolar targets with glottal plosives (e.g. /t/ → [ʔ]), glottal fricatives (e.g. /tʰ/ → [h]), pharyngealized plosives (e.g. /tʰ/ → [tˁ]), pharyngeal fricatives (e.g. /s/ → [ʕ]) or pharyngeal affricates (e.g. /ts/ → [ʔʕ]). The other six children (P3 – P8) produced alveolar plosive targets as velar plosives (e.g. /t/ → [k]). Two participants (P7 and P8) demonstrated lateral release in production of alveolar affricates (/ts/ → [tɬ]). One participant (P8) showed nasal release (e.g. /s/ → [sᴺ]) in production of alveolar targets. Two participants (P1 and P2) demonstrated other speech errors which are not related to the alveolar targets. These speech errors are not reported in Table 2. They were initial consonant deletion (e.g. k → [Ø], kʰ → [Ø]) for the participant P1; and initial consonant deletion and substitutions by glottal stops or fricatives (e.g. l → [Ø], p → [Ø], n → [Ø], kw, kwʰ → [h, w], f → [h], /k/ → [ʔ] , /kʰ/ → [h]) for the participant P2.

Seven children in Group NP (NP1-6, NP8) demonstrated speech distortions including lateralization, palatalization, or nasalisation of alveolar targets in the CSPT Part I or in the deep test. Five children in Group NP (NP1, NP3, NP5, NP6, NP8) produced lateral fricatives or affricates (e.g. /s/ → [ɬ] , /ts/ → [tɬ]). Two children (NP1 and NP2) produced palatalized fricatives (e.g. /s/ → [sʲ]). Another two children in Group NP (NP5, NP6) showed nasal release in realizations of alveolar targets (e.g. /ts/ → [tsᴺ], /s/ → [sɬᴺ]). One child (NP4) demonstrated nasal snort which is a velopharyngeal fricational noise (e.g. /s/ → [sᴺˢ], /ts/ → [tsᴺˢ]) (see Eurocleft Speech Group, 1993, p.150, for definition). Speech errors in the CSPT Part I were reported only for the participant (NP4) (due to procedural errors in the testing process). The participant (NP7) demonstrated lateral fricatives in his spontaneous speech in the CSPT Part II. Three participants (NP2, NP4 and NP5) demonstrated other speech errors that are not involving the alveolar targets. These errors are not reported in Table 2. including labialized fricatives (e.g. /f/ → [fʷ]) for the participant NP2; glottal fricatives (e.g. /f/ → [h]) for the participant NP4; and cluster reduction or substitution (e.g. /kw/ → [w], /k/ → [j]) for the participant NP5.

Stimuli

Test items were the words /$t^h au_4$/ 'head' and /$k^h au_4$/ 'ball'. Both words are within the vocabularies of young Cantonese children. Both are concrete and meaningful so children have no *a priori* reason to favor one choice over the other. These stimuli were identical to used by Whitehill et al. (2003) and were used with permission. The pair of words was used to construct an eight-interval continuum in which the perceptual change from /$t^h au_4$/ to /$k^h au_4$/ was accomplished by variation in the onset frequency of F3 only. F3 onset was 3109.00 Hz for the first token and decreased to 2189.51Hz for the eighth token. Stimulus parameters are detailed in Whitehill et al. (2003).

Two types of stimulus sequences were created – those for the identification task and those for the discrimination task. For the identification task, each stimulus was presented alone to the listeners in random order. For discrimination, each token was paired with itself and with tokens one or two steps away in the series. A short inter-stimulus interval (ISI) of 500 ms was used to minimize memory requirements (Fujisaki & Kawashima, 1971; Pisoni, 1973).

Procedures

The subjects were tested in a quiet room as on the same day of the screening procedures. Stimuli were played to the listeners via a Runtime Revolution programme running on a Macintosh PowerBook G4. Presentation was via Sennheiser HD 580 closed headphones.

The identification task was identical to that described by Whitehill et al. (2003) based on a two-alternative forced-choice response procedure. The task consisted of 11 blocks of each of the eight stimuli presented in random order; one trial for each of the eight test stimuli. The subjects identified the stimulus by clicking on one of the two pictures: a picture of a head, representing the stimulus /$t^h au_4$/, or a picture of some soccer balls, representing the stimulus /$k^h au_4$/. The first block was the practice block and was not scored, but the subjects were not told about this.

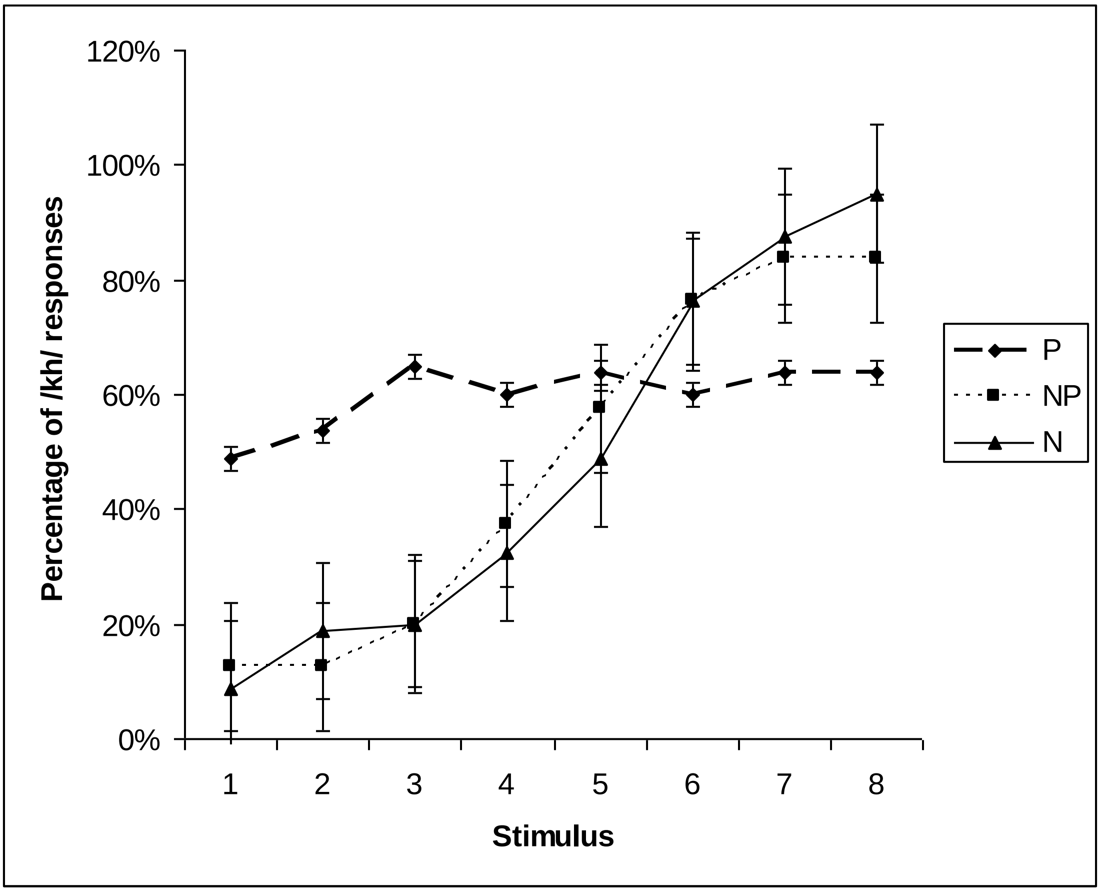
The discrimination tasks consisted of same-different (AX) judgments for stimulus pairs. Each task contained physically different as well as identical pairs. The subjects were presented five series of the twenty – one stimulus pairs. Each series consisted of one identical pair for each of the eight stimuli, one physically different pair for each of the seven possible 1-step comparisons (1-2, 2-3, 3-4, 4-5, 5-6, 6-7, 7-8) and six possible 2-step comparisons (1-3, 2-4, 3-5, 4-6, 5-7, 6-8). The identical pairs were treated as dummies explicitly intended to elicit "same" responses. In each series, the pairs were randomly ordered with an intrapair interstimulus interval of 500 ms. The first series was the practice block and the score was not counted. The subjects were required to clicking on one of the two response blocks: ‘same’ or ‘different’, on the screen.

Results

Identification

Identification functions were obtained by calculating the percentage of /k^h/ responses for each stimulus (1-8) along the eight-step continuum for each group. The identification functions with standard error bars for the three groups of participants are displayed in Figure 1.

Figure 1. Identification functions for each group. The percentage of /k^h/ responses is plotted against the eight stimuli on the /t^h-k^h/ continuum for Group P, Group N and Group NP.



The identification functions for both Group NP and Group N showed sharper slopes than the Group P children. The identification functions for Group NP and Group N showed that they identified the stimuli along the continuum into distinct categories. Variability between group NP and Group N was low, as indicated by the standard error bars in Figure 1. The point at which the identification function is 50% can be determined as the phonemic boundary along a speech stimulus continuum (Repp & Liberman, 1987). The phonemic boundary of both Group N and Group P children were found to lie between stimulus 4 and stimulus 5. The children in Group NP and Group N consistently identified the stimuli to the left of the phonemic boundary as /t^h/ while those stimuli to the right of the boundary as /k^h/. That means the two groups of children generally identified stimuli 1-3 with F3 onset frequencies above 2600 Hz as /t^h/, while stimuli 5-8 with F3 onset frequencies below 2600 Hz as /k^h/.

The identification function for Group P was flatter than that for Group NP and Group N. The range of percentage of /k^h/ response was from 48.8% to 63.8% for the speech tokens 1-8 along the stimulus continuum. This suggests Group P children with repaired cleft palate and posterior placements identified the speech tokens at chance level and no distinct categories were found along the /t^h-k^h/ continuum.

Table 3 shows the identification patterns for each child in Group NP and Group N. All Group NP and Group N children showed distinct categories in identification of the stimuli along the speech continuum. The phonemic boundaries of the children in these two groups lay between stimulus 2 to stimulus 6 with the majority falling between stimulus 4 and stimulus 5. For example, the first child (NP1) in group NP identified stimuli 1-4 as /t^h/ with a criterion of 7 out of 10 responses. Stimulus 5 and stimulus 6 were identified at chance level, That is, they were identified less than 7 out of 10 times as one of the phonemes. Therefore the phonemic boundary of this child lies between stimulus 5 and stimulus 6. The stimuli on the right of the phonemic boundary (stimuli 7-8) were identified at above chance level as /k^h/.

Table 4 displays the individual identification performance for Group P children. There were no distinct phoneme categories for the two phonemes or no identifiable phonemic boundaries for any of the children in this group. Many stimuli were identified at chance level (less than 7 out of 10 times). For example, participant P2 identified the stimuli 1-2 and 4-7 at chance level without discrete phonemic spaces for the two phones or a distinct phonemic boundary. When a phoneme was identified (i.e. at least 7 out of 10 times), it was more likely to be identified as /k^h/. For example, participants P3, P6, P7 and P8, have never identified a stimulus as /t^h/.

Table 3. Identification of each stimulus by Group NP and Group N.

	Stimulus							
Participant	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
NP1	t	t	t	t	-	-	k	k
NP2	t	t	-	-	-	k	k	k
NP3	t	t	t	-	k	k	k	k
NP4	t	t	t	t	-	-	k	k
NP5	t	t	t	-	k	k	k	k
NP6	t	t	t	t	t	-	k	k
NP7	t	t	t	-	-	k	k	k
NP 8	t	t	t	t	-	k	k	k
N1	t	t	t	-	k	k	k	k
N2	t	-	-	-	-	k	k	k
N3	t	-	-	k	k	k	k	k
N4	t	t	t	t	t	k	k	k
N5	t	t	t	t	-	k	k	k
N6	t	t	t	t	-	k	k	k
N7	t	t	t	t	t	k	k	k
N 8	t	t	t	t	t	-	k	k

Note. The criterion for identification was 7 out of 10 responses. A dash indicates that the stimulus was identified at chance level (below 7 out of 10 responses). Shaded areas represent the apparent phonemic boundary.

Table 4. Identification of each stimulus by Group P.

	Stimulus							
Participant	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
P1	t	t	t	t	t	t	t	t
P2	-	-	k	-	-	-	-	t
P3	k	k	k	k	k	k	k	k
P4	t	t	t	-	-	-	-	-
P5	k	-	k	t	-	t	-	-
P6	k	k	k	k	k	k	k	k
P7	t	-	k	k	k	k	k	k
P8	-	-	-	-	-	-	-	k

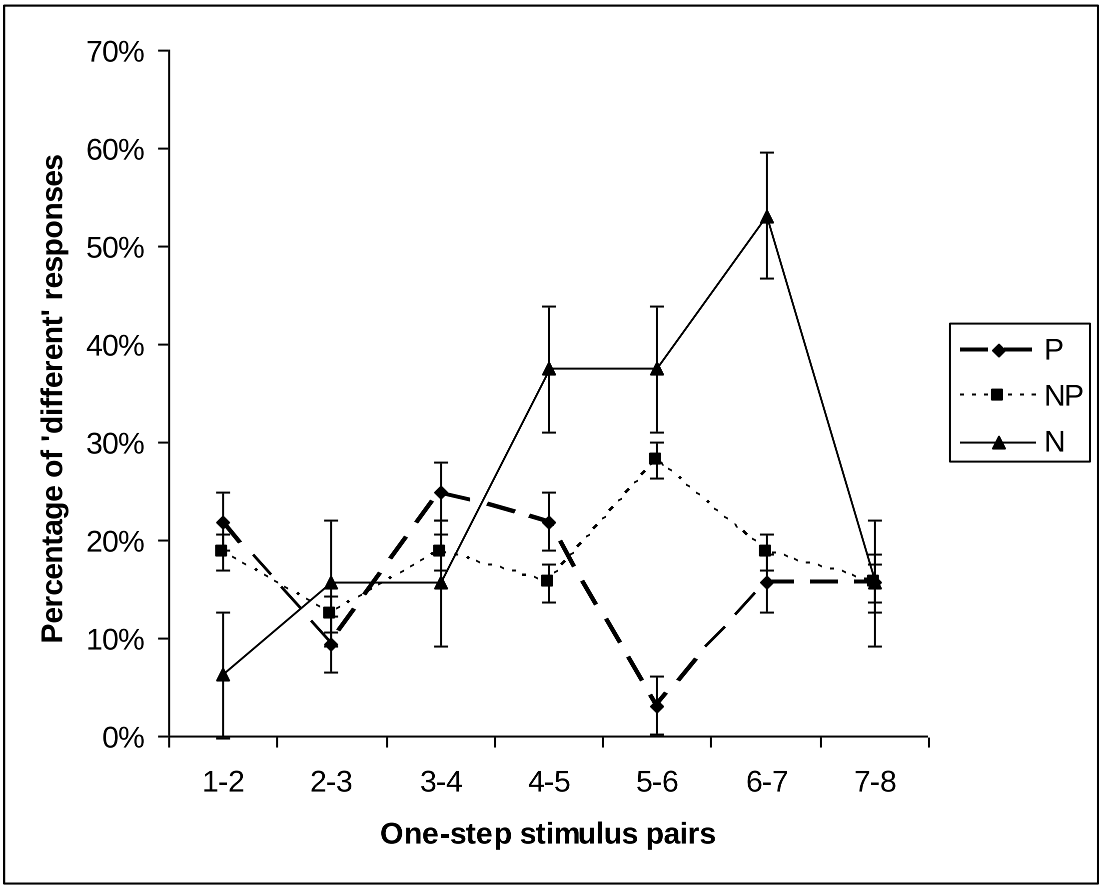
Note. The criterion for identification was 7 of 10 responses. A dash indicates that the stimulus was identified at chance level (below 7 out of 10 responses).

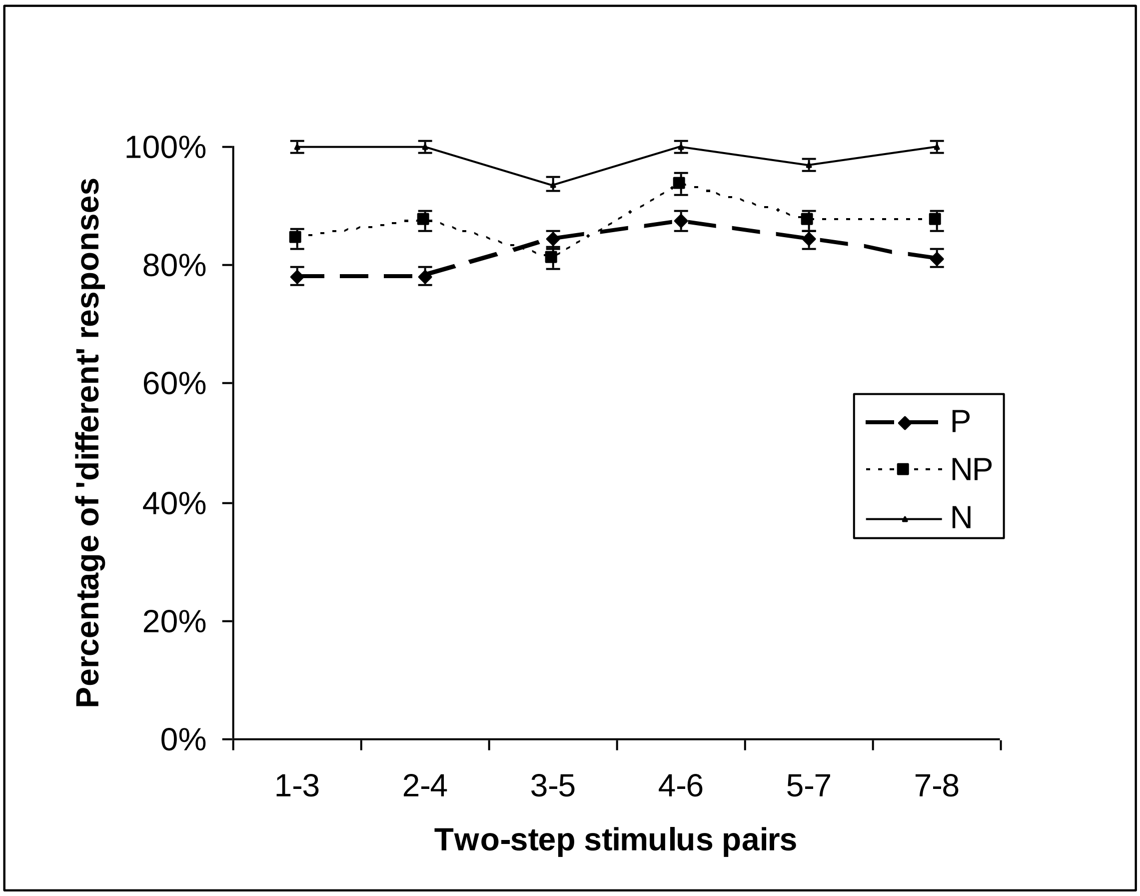
Discrimination

The group discrimination functions are shown in Figure 2. For one-step comparisons, all three groups discriminated the stimuli pairs at chance level. That is, all children gave below 53% ‘different’ responses to the one step stimulus pairs. The discrimination functions for both Group P and Group NP children were flat, showing both groups performed similar in the discrimination task along the continuum. The standard error bars for Group N in one-step comparisons showed that Group N discrimination function was at higher level for stimulus pairs 4-5, 5-6, 6-7. This indicates Group N children could generally discriminate between-phonemic boundaries stimulus pairs better than within- phonemic boundaries stimulus pairs. For two step comparisons, all three groups could discriminate the stimulus pairs above chance level (the groups gave above 78% ‘different’ responses to the two step stimulus pairs).

The percentage of 'different' responses was entered into a 3 (group) x 13 (stimulus pairs) mixed – design analysis of variance (ANOVA). There were no significant group differences in the percentage of 'different' responses, $F(2, 21) = 1.93$, $p = 0.169$. There was a significant effect of the stimulus pairs, $F(12, 252) = 64.29$, $p = 0.000 < 0.005$. Post hoc analysis showed that significant higher percentage of 'different' responses was found in two step comparison than in one step comparison.

Figure 2. Discrimination functions for each group. The percentage of 'different' responses were plotted as a function of the one-step comparisons or two-step comparisons along the /t^h-k^h/ continuum for Group P, Group NP and Group N.





Discussion

The aim of this study was to determine the abilities of children with repaired cleft palate and with posterior placement to identify and to discriminate stimuli along the /t^h-k^h/ speech continuum. The performance of children with cleft palate and posterior placement (Group P) was compared with two control groups: children with repaired cleft palate without posterior placement (Group NP) and normally developing children without cleft palate (Group N). In identification, the children in both control groups (Group NP and Group N) showed clear phonemic boundaries between /t^h/ and /k^h/ and thus appeared to perceive the stimuli along the /t^h-k^h/ speech continuum in two distinct phonemic categories. In contrast, the children with repaired cleft palate and posterior placement (Group P) identified all the stimuli along the /t^h-k^h/ speech continuum at chance level and thus appeared not to perceive a phonemic boundary between /t^h/ and /k^h/ or any discrete acoustic spaces along the /t^h-k^h/ continuum. In the discrimination task, all three groups could discriminate the two-step stimulus pairs at better than chance level whereas all three groups discriminated the one-step stimulus pairs at chance level along the /t^h-k^h/ continuum. There were no group differences among the three groups of children in the discrimination task.

Group P children identified the stimuli (1-8) along /t^h-k^h/ continuum at chance level. Group NP and Group N children perceived the stimuli into two distinct acoustic spaces with a discrete phonemic boundary between /t^h/ and /k^h/. This result is consistent with several previous studies showing that children with phonological disorders had perceptual deficits that were related to their production errors (Broen, Strange, Doyle, & Heller, 1983; Groenen, Crul, Maassen, & Van Bon, 1996; Groenen et al., 1998; Raaymakers & Crul, 1988). The identification results of the present study were consistent with that of Whitehill et al. (2003). The current experimental design did not investigate the direction of the relationship between production and perception. Therefore, the position that production errors may lead to perceptual deficits or that perceptual deficits may lead to production errors may be possible explanation to the present results (Whitehill et al., 2003).

The position that perception follows production could be accounted for the motor theory of speech developed by Liberman, Cooper, Shankweiler & Studdert-Kenndey, (1967) as well as several previous supporting studies (e.g. Hoffman et al., 1985; Monnin & Huntington, 1974). The direct realist theory of speech perception also supports the position that perception follows production (Fowler, 1981, 1984, 1986, 1989, 1994, 1996). The theory assumes that speakers produce gestures and listeners perceive them. Therefore, forms of speech production are highly correlated with listeners' perceptual judgments (see supporting studies e.g. Diehl & Kluender, 1987; Diehl, Lotto, & Holt, 2004; Fowler, 1986; Liberman, 1996).

The general approach to speech perception gives an alternative account of the correlation between speech production and perception. This approach supports both views that perception follows production; and production follows perception (see supporting studies e.g. Diehl & Kluender, 1987). For perception follows production, the general approach claims that listeners do not perceptive gestures, but they do recognize the acoustic consequences of gestures. Since regularities of speech production will be reflected in the acoustic signal, listeners make use of the acoustic correlates of these production regularities in judging the phonemic content of speech signals (for a review, see Diehl et al., 2004).

Other ways to account for the relationship between production and perception are according to the two-lexical model developed by Hewlett (1990). Hewlett (1990) suggested that the input lexicon contains phonological representations, which are perceptually based and reflect the phonological contrasts available to the child in decoding speech. The output lexicon contains corresponding phonological representations, which are articulatory based and reflect the child's production abilities. There are realization rules which map perceptual representations onto articulatory representations (Hewlett, 1990). The Group P children with cleft palate and posterior placement would have full phonological information including the realization rules and the specification of the sounds in their output lexicon, but they may have different phonological representations or realization rules for the phonological contrasts of the /t^h/ and /k^h/, and hence leading to the identification deficits of the /t^h – k^h/ contrast.

Group P children tended to identify the stimulus as /k^h/ and this result supports the lexical avoidance discussed by Schwartz & Leornard (1982). The Group P children apparently choose the sound they use and avoid the target sound that beyond their output lexicon (i.e. they tended to select the /k^h/ responses in the identification task). Schwartz & Leonard's (1982) explanation of lexical avoidance can be applied with the Hewlett's model. Group P children may have been unable to devise a motor plan for the alveolar sounds and they will simply have no rule at all for associating the relevant input representations for the alveolar sounds (e.g. /t^h/) with the corresponding out representations. This might explain why the posterior placememnt persist even after surgical repair (McWilliams et al., 1990). Change in articulation or the target contrasts could happen only if the speaker were persuaded, for some reason, to access the targets again from the input lexicon and devise a new motor plan (Hewlett, 1990). Therefore, the result supports the view that articulatory errors initially occuring as a result of structural constraints imposed by the cleft lip and palate become integrated into the children's phonological system (Chapman, 1993).

In order for the phonetic production of a sound to be revised, the speaker has to acquire the awareness of the insufficiency of the current production and the knowledge of the relevant crucial articulatory targets (Hewlett, 1990). Therefore a speech therapy programme involving a perception component is recommended to children with cleft palate and production errors. Previous studies have shown that training on auditory perception of misarticulated phonemes improved performance on both production and auditory perception tasks (see e.g. Bradlow, Pisoni, Akahane-Yamada, & Tohkura, 1997; Kosky & Boothroyd, 2003). The present results recognize that children with cleft palate and posterior placement showed phonetically based identification deficits related to their speech production errors but not auditory based discrimination difficulties. Therefore, training in perceptual identification of the misarticulated phonemic contrasts is recommended in order to stimulate the children to access the targets again from the input lexicon and devise a new motor plan for the alveolar targets (Hewlett, 1990).

There were no significant group differences in the discrimination performance among the three groups of children in this study. Group P Children with cleft palate and posterior placement displayed deficits in identifying speech stimuli along the /t^h-k^h/ continuum. However, they did not show any deviations in discrimination of speech stimulus pairs along the /t^h-k^h/ continuum, when compared with the two groups of age-matched controls (Group NP and Group N). According to a dual-coding structure of auditory and phonetic processing model (see e.g. Sawusch & Mullennly, 1985; Sawusch & Nusbaum, 1983), speech perception involves a preliminary auditory analysis, further auditory and phonetic feature analysis, and the collaboration of phonetic features into a phonemic representation (Cutting & Pisoni, 1978; Pisoni & Sawusch, 1975). Information can be placed in short-term memory at any stages in the speech processing. Auditory processing includes a preliminary analysis and is related to auditory short-term memory; whereas, phonetic processing includes phonemic labeling strategies is related to phonetic memory (Tartter, 1982). The occurrence of identification deficits without concomitant discrimination difficulties provides evidence to the possible underlying phonetic memory based deficits in children with cleft palate and posterior placement in perception of /t^h/ and /k^h/ sounds.

According to Fujisaki and Kawashima's model, when listener discriminates two different phonetic types, he uses the derived phonetic properties and features of the auditory stimulus as represented in some type of phonetic short-term memory. This listener determines whether the two stimuli have been identified belonging to the same or different phonetic categories with a binary decision. Following this strategy, a listener's performance in a discrimination task should be completely predictable from his performance on an identification task and should approach the ideal case of categorical perception (Pisoni, 1973). This listener can discriminate two stimuli only to the extent that he can identify the stimuli as being different phonetic segments (Liberman et al., 1957). Nonetheless, all three groups of children showed no significant group differences in discriminating stimuli within or between phonetic segments, that is, the identification performance has not predicted the discrimination performance in the three groups. One possible explanation is that they may have used some stored auditory information based on the acoustic parameters of the stimuli as presented in the auditory short-term memory. They may have made a comparative judgment rather an absolute judgment, attending to specific acoustic properties of the two stimuli. As a consequence, discrimination performance is independent to identification. This might be consistent to the Hewlett's (1990) model that Group P children may have different realization rules or representations but they do not show auditory encoding problem onto the input representations.

The same-different judgment task used in this study may have encouraged the children to make direct comparison of stimuli for fine acoustic differences in the stimulus pairs along the /t^h-k^h/ continuum (Gerritis & Schouten, 2004). In order to further examine the relationship between the identification and discrimination performance of the children, a discrimination task that may encourage application of phonetic labeling strategies (for example, an two-interval two-alternative forced-choice (2I2AFC) discrimination task in which the stimuli are always different and the participants have to determine the order in which they are presented (AB or BA)) can be used

(Gerritis & Schouten, 2004). The children apparently required a greater physical distance between the stimuli for discrimination. Nonetheless, as shown by the non-overlapping standard error bars at the point of between-boundaries stimulus pairs of the discrimination functions of Group N, normally developing children could discriminate between-boundaries stimulus pairs generally better than within-boundary stimulus pairs in one step comparison along the /t^h-k^h/ continuum. However, Group P and Group NP children have not displayed any stimulus effects in the one step comparison. It appears that, the normally developing children (Group N) are more sensitive to the fine acoustic differences in the one step between – boundaries stimulus pairs than the children with cleft palate (Group P and Group NP). In order to identify more specific acoustic differences required for discrimination in the three groups of children, the discrimination performance on speech stimuli with physical distances varied in between the one – step and two – step stimulus pairs (that is an acoustic difference of 150 Hz F3 onset frequency) could be further investigated.

In the current study, only one phonemic contrast (t^h-k^h) was investigated in the identification and discrimination tasks. It is not known whether the children with posterior placement demonstrate a more general perceptual deficit, affecting other contrasts. Investigating the children's perception on their correctly articulated phonemic contrasts will help to evaluate the specific relationship between the perceptual and production errors. Finnegan (1974) determined the discrimination abilities of children with cleft palate on a variety of phonological contrasts showing the children with cleft palate had poorer speech discrimination abilities when compared with age-matched controls. When compared to the present study, further investigation on the perception of other phonemic contrasts would be of interest to evaluate the extent of perceptual deficits in children with cleft palate and posterior placement.

The present results were consistent to the previous studies claiming that identification tasks involve phonemic judgments, which is considered more relevant to investigations of phonological disorder than discrimination tasks (Groenen et al., 1998; Monnin & Huntington, 1974; Raaymakers & Crul, 1988; Rvachew & Jamieson, 1989). With regards to the identification deficits demonstrated by the children with cleft palate but without concomitant discrimination deficits, further studies on the perception abilities of children with cleft palate are clearly need, as speech processing deficits related to the phonetic memory is found in children with cleft palate and posterior placement in the present study.

Acknowledgements

I thank my supervisor, Professor Tara Whitehill, for her invaluable guidance on this dissertation. I am grateful to the Joint Cleft Clinic of the Prince Philip Dental Hospital, and the children and their parents for participating. I acknowledge with thanks Dr. Alex Francis, who prepared the stimuli for the identification task (for the Whitehill et al. (2003) study).

References

Baddeley, A. (1986). *Working memory*. Oxford: Clarendon Press.

Baddeley, A. (1992). Working memory. *Science, 255*, 556-559.

Bradlow, A. R., Pisoni, D. B., Akahane-Yamada, R., & Tohkura, Y. (1997). Training Japanese listeners to identify English /r/ and /l/: IV. Some effects of perceptual learning on speech production. *Journal of the Acoustical Society of America*, *101*(4), 2299-2310.

Broen, P. A., Strange, W., Doyle, S. S., & Heller, J. H. (1983). Perception and production of approximant consonants by normal and articulation-delayed preschool children. *Journal of Speech and Hearing Research, 26*(4), 601-608.

Chapman, K. L. (1993). Phonologic processes in children with cleft palate. *Cleft Palate-Craniofacial Journal*, *30*, 64-72.

Cooper, M. E., Stone, R. A., Liu, Y-E., Hu, D-N., Melnick, M., & Marazita, M. L. (2000). Descriptive epidemiology of nonsyndromic cleft lip with or without cleft palate in Shanghai, China, from 1980 to 1989. *Cleft Palate-Craniofacial Journal, 37*, 274-280.

Cutting, J. E., & Pisoni, D. B. (1978). An information-processing approach to speech perception. In J. F. Kavanagh, & Strange, W. (Eds.), *Speech and language in the laboratory, school and clinic* (pp. 38-87). Cambridge, MA: The MIT Press.

Diehl, R. L., & Kluender, K. R. (1987). On the categorization of speech sounds. In S. Harnad (Ed.), *Categorical perception*. London: Cambridge University Press.

Diehl, R. L., Lotto, A. J., & Holt, L. L. (2004). Speech perception. *Annual Review of Psychology, 55*, 149-179.

Eimas, P. D. (1963). The relation between identification and discrimination along speech and nonspeech continua. *Language & Speech, 6*, 206-217.

Eurocleft Speech Group. (1993). Cleft palate speech in a European perspective: Eurocleft speech project. In P. Grunwell (Ed.), *Analysing cleft palate speech*. London: Whurr.

Finnegan, D. E. (1974). Speech sound discrimination skills of seven- and eight-year-old cleft palate males. *Cleft Palate Journal, 11*, 111-121.

Fowler, C. A. (1981). Production and perception of coarticulation among stressed and unstressed vowels. *Journal of Speech & Hearing Research, 24*, 127-139.

Fowler, C. A. (1984). Segmentation of coarticulated speech in perception. *Perception & Psychophysics, 36*, 359-368.

Fowler, C. A. (1986). An event approach to the study of speech perception from a direct realist perspective. *Journal of Phonology, 14*, 3-28.

Fowler, C. A. (1989). Real objects of speech perception: A commentary on Diehl and Kluender. *Ecological Psychology, 1*, 145-160.

Fowler, C. A. (1994). Speech perception: Direct realist theory. In R. E. Asher (Ed.), *The encyclopedia of language and linguistics* (pp. 4199-4203). Oxford: Pergamon.

Fowler, C. A. (1996). Listeners do hear sounds, not tongues *Journal of Acoustical Society of America, 99*, 1730-1741.

Fujisaki, H., & Kawashima, T. (1971). A model of the mechanisms for speech perception: Quantitative analysis of categorical effects in discrimination. *Annual Report of the Engineering Research Institute, Faculty of Engineering, University of Tokyo, 30*, 59-68.

Gathercole, S. E., & Baddeley, A. D. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language, 29*, 336-360.

Gerrits, E., & Schouten, M. E. H. (2004). Categorical perception depends on the discrimination task. *Perception & Psychophysics, 66*(3), 363-376.

Gibbon, F. E., Ellis, L., & Crampin, L. (2004). Articulatory placement for /t/, /d/, /k/ and /g/ targets in school age children with speech disorders associated with cleft palate. *Clinical Linguistics & Phonetics, 18*(6-8), 391-404.

Groenen, P., Crul, T., Maassen, B., & Van Bon, W. (1996). Perception of voicing cues in children with early otitis media with and without language impairment. *Journal of Speech and Hearing Research 39*, 43-54.

Groenen, P., Maassen, B., & Crul, T. (1998). Formant transition duration and place perception in misarticulating children and adolescents. *Clinical Linguistics & Phonetics, 12*, 439-457.

Groenen, P., Maassen, B., Crul, T., & Thoonen, G. (1996). The specific relation between perception and production errors for place of articulation in developmental apraxia of speech. *Journal of Speech & Hearing Research, 39*(3), 468-483.

Hardin-Jones, M. A., & Jones, D. L. (2005). Speech production of preschoolers with cleft palate. *Cleft Palate Craniofacial Journal, 42*(1), 7-13.

Hewlett, N. (1990). Processes of development and production. In P. Grunwell (Ed.), *Developmental speech disorders* (pp. 17-36). London: Churchill Livingstone.

Hoffman, P. R., Daniloff, R. G., Bengoa, D., & Schuckers, G. H. (1985). Misarticulating and normally articulating children's identification and discrimination of synthetic /r/ and /w/. *Journal of Speech and Hearing Disorders, 50*, 46-53.

International Organization for Standardization. (1985). *Recommendation R 389: Standard reference zero for the calibration of pure-tone audiometers* (2nd ed.). Basel, Switzerland: Author.

Kosky, C., & Boothroyd, A. (2003). Perception and production of sibilants by children with hearing loss: A training study *The Volta Review, 103*(2), 71-98.

Liberman, A. M. (1996). Introduction: some assumptions about speech and how they changed In *Speech: A Special Code*. Cambridge, MA: MIT Press.

Liberman, A. M., Cooper, F. S., Shankweiler, D. P., & Studdert-Kennedy, M. (1967). Perception of the speech code. *Psychological Review, 74*, 431-461.

Liberman, A. M., Harris, K., Hoffman, H. S., & Griffith, B. C. (1957). The discrimination of speech sounds within and across phoneme boundaries. *Journal of Experimental Psychology, 54*, 358-368.

McWilliams, B. J., Morris, H.L., & Shelton, R.L. (1990). *Cleft palate speech (2nd ed.)*. Toronto: B.C. Decker.

Monnin, L. M., & Huntington, D. A. (1974). Relationship of articulatory defects to speech-sound identification. *Journal of Speech and Hearing Research, 17*, 352-366.

Ohde, R. N., & Sharf, D. J. (1988). Perceptual categorization and consistency of synthesized /r-w/ continua by adults, normal children and /r/-misarticulating children. *Journal of Speech and Hearing Research, 31*, 556-568.

Peterson-Falzone, S. J., Hardin-Jones, M.A., & Karnell, M.P. (2001). *Cleft palate speech (3rd ed.)*. St Louis, MO: Mosby.

Pisoni, D. B. (1973). Auditory and phonetic memory codes in the discrimination of consonants and vowels. *Perception & Psychophysics, 13*, 253-260.

Pisoni, D. B., & Sawusch, J. R. (1975). Some stages of processing in speech perception. In A. Cohen & S. G. Nooteboom (Eds.), *Structure and process in speech perception* (pp. 16-34). Berlin-Heidelberg-New York: Springer-Verlag.

Raaymakers, E. M. J. A., & Crul, T. A. M. (1988). Perception and production of final /s-ts/ contrast in Dutch by misarticulating children. *Journal of speech and Hearing Disorders, 53*, 262-270.

Repp, B. H., & Liberman, A. M. (1987). Phonetic category boundaries are flexible. In Harnad (Ed.), *Categorical perception*. Cambridge, U.K: Cambridge University Press.

Russell, J., & Grunwell, P. (1993). Speech development in children with cleft lip and palate. In P. Grunwell (Ed.), *Analysing cleft palate speech* (pp. 19-47). London: Whurr.

Rvachew, S., & Jamieson, D. G. (1989). Perception of voiceless fricatives by children with a functional articulation disorder *Journal of Speech and Hearing Disorders*, *54*, 193-208.

Santelmann, L., Sussman, J., & Chapman, K. (1999). Perception of middorsum palatal stops from the speech of three children with repaired cleft palate. *Cleft Palate Craniofacial Journal, 36*(3), 233-242.

Sawusch, J. R., & Mullennly, J. W. (1985). When selective adaptation and contrast effects are distinct: A reply to Diehl, Kluender and Parker. *Journal of Experimental Psychology: Human Perception and Performance, 11*, 242-250.

Sawusch, J. R., & Nusbaum, H. C. (1983). Auditory and phonetic processing in place perception for stops. *Perception and Psychophysics, 34*, 560-568.

Schwartz, R.G. & Leonard, L. B. (1982). Do children pick and choose? An examination of phonological selection and avoidance in early lexical acquisition. *Journal of Child Language, 9*, 319-336

Tartter, V. C. (1982). Vowel and consonant manipulations and the dual-coding model of auditory storage: A re-evaluation. *Journal of Phonetics*, *10*(2), 217-223.

Whitehill, T. L., Francis, A. L., & Ching, C. K-Y. (2003). Perception of place of articulation by children with cleft palate and posterior placement. *Journal of Speech, Language, and Hearing Research*, *46*, 451-461.

Appendix A. Deep Test Stimuli

Stimulus	Chinese Word	English Meaning	Phonetic transcription
1	地	Floor	tei_6
2	刀	Knife	tou_1
3	踢	Kick	$t^hɛk_2$
4	碟	Plate	tip_6
5	電話	Telephone	tin_6 wa_6
6	蝴蝶	Butterfly	wu_4 tip_6
7	T	Letter T	t^hi_1
8	頭	Head	$t^hɐu_4$
9	糖	Candy	$t^hɔŋ_4$
10	天	Sky	t^hin_1
11	兔仔	Rabbit	t^hou_3 $tsɐi_6$
12	滑梯	Slide	wat_6 $t^hɐi_1$
13	遮	Umbrella	$tsɛ_1$
14	袖	Sleeve	$tsɐu_6$
15	粥	Congee	$tsuk_1$
16	汁	Juice	$tsɐp_1$
17	枕頭	Pillow	$tsɐm_2$ $t^hɐu_4$
18	筷子	Chopsticks	fai_2 tsi_2
19	車	Car	$ts^hɛ_1$

20	草	Grass	ts^{h}ou$_{2}$
21	賊	Robber	ts^{h}ak$_{6}$
22	7	Seven	ts^{h}ɐt$_{1}$
23	廚房	Kitchen	ts^{h}y$_{4}$ fɔŋ$_{6}$
24	間尺	Ruler	kan$_{3}$ ts^{h}ɛk$_{2}$
25	蛇	Snake	sɛ$_{4}$
26	梳	Comb	sɔ$_{1}$
27	錫	Kiss	sɛk$_{2}$
28	衫	Shirt	sam$_{1}$
29	洗面	Wash face	sɐi$_{2}$ min$_{6}$
30	巴士	Bus	pa$_{1}$si$_{2}$
31	梨	Pear	lei$_{5}$
32	籮	Basket	lɔ$_{1}$
33	6	Six	luk$_{6}$
34	蠟	Candle	lap$_{6}$
35	落雨	Rain	lɔk$_{6}$ jy$_{5}$
36	行雷	Thunderstorm	haŋ$_{4}$ lœy